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The Geology of East Gippsland

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Abstract

Five broadly defined landforms are discriminated in east Gippsland. A mountainous tract is flanked on the N. by extensions of the Monaro Tableland, and on the S. by piedmont downs. These in turn are fringed by a Quaternary dune-swamp complex, and small intermontane basins, largely due to differential erosion, occur within the mountain tract.

Karst features occur in a few areas but the dominant regimen is fluvial. Effects of Pleistocene periglaciation can be discerned on the highest peaks.

The bedrock consists of a complex of tightly folded Ordovician terrigenous sediments, and less strongly folded Silurian terrigenous and carbonate sediments. These are intruded and metamorphosed by a number of latest Silurian or earliest Devonian granitic bodies, of which the largest are the Bega and Kosciusko batholiths.

Early Devonian times witnessed the accumulation of a great thickness of terrestrial sediments, the waxing and waning of acid vulcanism (Timbarra Formation and Snowy River Volcanics), block faulting and planation, followed by a widespread marine incursion and the deposition of the limestone-mudstone complex of the Buchan Group. A period of folding sometime in the Middle Devonian or earliest Upper Devonian (Tabberabberan Orogeny) affected the entire region, and was followed by a further cycle of acid vulcanism (Eden Rhyolites) and essentially continental sedimentation (Merrimbula Group). Further plutonism in late Devonian and late Triassic times is exemplified by the Ellery Granodiorite massif and the syenite-granite porphyry complexes of the Benambra-Mt. Leinster area.

Cainozoic basalts, whose placement reflects generally the mid-Tertiary drainage pattern, occur scattered across the area. Cainozoic sediments are generally restricted to the piedmont-cum-coastal area and are predominantly non-marine, with the notable exception of the Oligocene to Lower Pliocene marine sediments, including limestones, occurring W. of Orbost (Lakes Entrance Formation, Gippsland Limestone, Tambo River Formation and Jemmy's Point Formation).

The incursion reached its maximum in Miocene times. The last events were the deposition of a widespread veneer of sands and gravels in late Pliocene to Pleistocene times (Haunted Hills Gravels) followed in late Pleistocene to Holocene by formation of coastal barriers, lagoons, marshes and alluvial deposits arranged *en echelon* along the coast; these sediments include evidence of a mid-Holocene high sea-level.

The structural evolution of this and immediately adjacent parts of the State is discussed, with particular reference to fault systems and the evidence for wrench faulting not previously noted. The area has been subjected to at least four periods of diastrophism, each of which has produced less intense folding than its predecessor. The Cainozoic was characterized by minor faulting and mild warping.

A brief account is given of the economic geology of the region: minor goldfields in the Bendoc-Bonang, Club Terrace and South Buchan-Mt. Tara areas; small silver-lead mines in the Buchan and Deddick areas; small copper mines at Deddick and Sardine Creek; and iron and manganese shows in the Buchan-Nowa Nowa district. The greatest economic potential appears to lie in the Silurian marbles, the Devonian dolomites and limestones, and the soft Miocene limestones, all of which are present in large bodies.

Introduction

The boundary chosen for the East Gippsland Symposium neatly bisects the region between Buchan, Bindi, Benambra and the Cobberas, where recent investigations have helped to delineate better the Palaeozoic history of the State. The area treated in the present account therefore extends somewhat to the W. of this line, as far as the Tambo R. valley.

The geology and geomorphology of Victoria E. of the Tambo R. was little known until recent years apart from early accounts of reconnaissance by W. B. Clarke (1853), N. Taylor (1866), and by an early government prospecting party led by J. S. Kost (1877). The most prolific early worker was A. W. Howitt (1869-1890) whose activities were confined to the area NW. of a line from Bairnsdale to Bonang. Other prominent contributors were J. Stirling (1884-1899), S. B. Hunter (1897-1898), W. H. Ferguson (1898-1899) and O. A. L. Whitelaw (1898-1921). A useful guide to the scattered literature is given by J. W. Gregory (1907). Since then there have been a number of papers on the Snowy River Volcanics (Samson & Cochrane 1947; Ringwood 1965a, 1965b; Fletcher 1963), and on the following districts: Nowa Nowa (Teale 1920; Bell 1959); Buchan (Talent 1956; Teichert & Talent 1958); Bindi (Gaskin 1943) Mt. Leinster (Broadhurst & Campbell 1933); on Upper Devonian sediments of the Club-Terrace-Combienbar-Buldah area (Spencer-Jones 1967), and on a number of mines in the counties of Tambo and Croajingalong. Relevant studies in adjoining areas are those of P. W. Crohn (1950) for the Omeo district; J. Carne (1897), I. A. Brown (1930, 1931) and L. R. Hall (1959, 1960) for the adjacent part of N.S.W.; E. C. Bird (1965) for coastal morphology of the Gippsland Lakes.

A recent programme of reconnaissance mapping E. of the Snowy R. and more

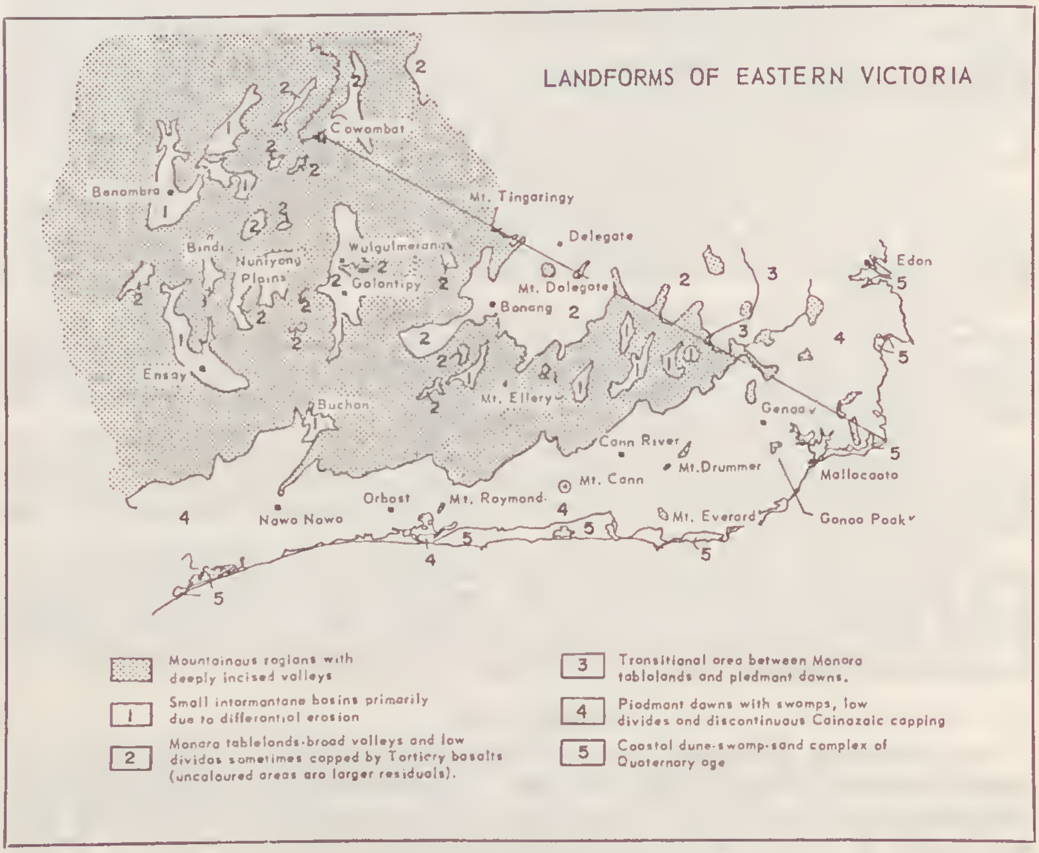

FIG. 1—Landforms of eastern Victoria.

detailed mapping on a scale of 1 mile to the inch of the country between the Tambo and the Snowy rivers has resulted in a clearer understanding of the geology of this part of the State.

Landforms

Five broadly visualized landforms can be discriminated in Victoria E. of the Tambo R.:

1. *Mountainous Tracts*: with deeply incised valleys, concordance of ridge tops often for many miles, and with occasional prominent mountain masses standing above these concordant summit levels as though they represented residuals projecting above a former widespread 'peneplain' or 'peneplains', e.g. The Cobberas, the Bowen Mountains, Mt. Tingiringi, Mt. Ellery and Mt. Elizabeth.

2. *The Monaro Tableland*: extending generally northwards from the mountainous tracts as a gently undulose surface consisting of broad valleys with low divides, scattered mid-Tertiary basalt residuals, and isolated monadnocks, e.g. Mt. Delegate, Wog Wog. A number of rather arbitrarily defined areas of near planar and gently undulose topography bevel the high parts more or less regardless of rock type. These can be construed as outliers of Monaro surface, many likewise including tracts of mid-Tertiary basalts, e.g. the Nunniong-Nunnet tablelands, the Wulgulmerang-Gelantipy-W Tree tablelands, and the gently rolling country N. of The Pilot about the headwaters of the Ingeegoodbee and Moyangul rivers. The Monaro surface falls in a general way SE. from Bombala, merging with the coastal downs in the headwaters of the Towamba and Wallagaraugh rivers.

3. *Piedmont Downs*: a complex of coastal tablelands, subdued ranges, swamps and generally weakly incised streams, though with isolated higher residuals, e.g. Mt. Cann, Mt. Everard, Mt. Raymond, Mt. Imlay and Genoa Peak. Low divides of moderate prominence occur, e.g. the Howe Ranges, the Tableland Hills, and the low ranges about Mt. Drummer. The boundary between the piedmont downs and the mountainous tract is often well defined and has a pronounced *en echelon* trend to the NE. suggesting some possibility of former warping in this direction; this has not been verified to date. There is a discontinuous cover of Cainozoic sands and gravels with probable mid-Tertiary basalts at Club Terrace and South Buchan testifying to the presence of at least some remnants of an earlier Tertiary surface within the complex. Part of the Cainozoic cover is post-Lower Pliocene, since similar beds in extension overlie marine Lower Pliocene sediments about Lakes Entrance. Other parts of the cover are notable for the presence of deep red soils some of which as for example between Cann R. and Cape Everard (E. D. Gill, pers. comm.), appear to have lateritic profiles indicative of a pre-Kalimnan age. In short, within this tract there is evidence for a complex of erosional and depositional surfaces of various Cainozoic ages, stripped and exhumed to varying degrees.

4. *Coastal Dunes*: sands and associated swamp and lacustrine deposits of late Quaternary age distributed *en echelon* along the coast. They include, across the mouths of streams, barriers which are responsible for the development of coastal lakes, particularly Tamboon Inlet, Sydenham and Mallacoota inlets, Lake Tyers, and Wonboyn Lake to the N. The geomorphic history of this region is little known but, like regions further to the W., notably the Gippsland Lakes, it includes the drowning of estuaries and a mid-Holocene high sea-level. This is indicated by dates of 3,780 and 3,560 years B.P. obtained from two superposed samples at Howe Flats, Mallacoota (E. D. Gill, pers. comm.).

5. *Intermontane Basins*: small areas due largely to differential erosion, e.g. Buchan, Bindi (Devonian limestones); Goongerah, Errinundra, Chandlers Creek, Ensay-Swifts Creek (granitic rocks); Cowombat (Silurian mudstones); Combienbar, Buldah (Upper Devonian sediments including mudstones). Earlier workers on adjacent areas of N.S.W. stressed the importance of faulting in the evolution of the landscape, and this opinion is still advocated, though with some reservations, by W. R. Browne (1967) for the highlands extending northwards from the Victorian border. Faulting of the Palaeozoic basement is widespread, but fault control of the landscape and Cainozoic movement along faults is all too often speculative. The dominant land forms are repeatedly explicable as the product of differential erosion, and to this should be added the natural tendency of granitic terrains to weather into linear scarps and depressions.

Minor karst features occur in the areas of Silurian marbles, Devonian limestones and dolomites and Tertiary limestones, more notably in the Limestone Ck-Stony Ck area (Stirling 1884), in the Buchan (Teichert & Talent 1958), Basin Ck, Bindi, Gillingal and Stony Ck (upstream from the Toorloo Arm of Lake Tyers) areas. In all of these the dominant regimen has been fluvial and the karst processes subordinate.

During Pleistocene times the highlands above 4,000 ft, particularly the peaks about the Cobberas, experienced periglacial conditions with developments of rock rivers and the stepping of valleys in association with boulder cascades (Talent 1965a).

Because the Cainozoic history of the area and its geomorphology are intermingled, reference should be made to the Cainozoic section of this paper.

Apart from the restricted plutonism and vulcanism in the Benambra-Mt. Leinster district in late Triassic times, Mesozoic events within the area are not well-known. Hence tectonism associated with this epoch remains speculative. However, the mid-Tertiary basaltic flows furnish a key to some reconstruction of the pre-basaltic relief, giving a measure of subsequent erosion. They provide too, perhaps, a check on the amount of displacement by Cainozoic faulting, now not discriminated over most of the area. At present this would seem the only means of checking the extent of Cainozoic unwarping of the highlands, for which Craft (1933b) arrived at an estimate of no more than 2,000 ft for the Monaro-Kosciusko region.

Stratigraphic Background

The sedimentary and plutonic history of eastern Victoria is complex, with a number of events discernible in different areas. The earliest, affecting the Ordovician basement, are masked by the complex of Silurian and post-Silurian tectonic and plutonic episodes.

No Cambrian rocks have been discovered, though at one stage it was thought that the metamorphic complex of north-eastern Victoria and the Omeo-Ensay district was of Cambrian age (Gregory 1903). With increased regional and detailed mapping, it became apparent that these rocks were in part, if not entirely, metamorphosed Ordovician sediments, originally argillites-cum-arenites. The metamorphic complex has become well known from the pioneer studies of A. W. Howitt (loc. cit.), and studies by C. M. Tattam (1929), P. W. Crohn (1950), and F. C. Beavis (1962), the latter in the Kiewa area. The main metamorphic complex is outside the region under particular attention, but small bodies of similar metamorphic rocks are found E. of the Omeo-Ensay belt: about Mt. Bung, E. of Benambra; about Mt. Misery and in the headwaters of Dead Horse Ck; S. of Davies

Plains; between Mt. Nunniong and Bindi and swinging down on to Junction Ck; as a dividing strip N. of Bentley and Nunnet plains; and as a zone 6 to 10 miles along strike extending S. from the Ellery Granodiorite. W. of Mt. Nunniong the schists and gneisses pass eastwards into lower grade schists and hornfels containing poorly preserved Eastonian graptolites, thus documenting the Upper Ordovician age of these particular metamorphosed sediments. The metamorphic belt extending southwards from the Ellery Granodiorite through Mt. Kuark and Murrungowar reappears as inliers in Cainozoic piedmont deposits, the largest about Mt. Raymond. The belt includes schists, gneisses and granulites as well as granitic bodies, but the most striking rock types are dark, coarse grained non-schistose or poorly schistose metamorphics. The abrupt truncation of this belt by the Ellery Granodiorite suggests tectonic complications of the boundary, or that the metamorphics and their intimately associated granitic bodies antedate intrusion of the Ellery massif. From the relationships between granitic intrusions and metamorphics to the W., one would assume that here too metamorphism took place about the close of Silurian or earliest Devonian times, with some possibility of development during the more indefinite early Silurian diastrophism.

ORDOVICIAN

The Ordovician sediments of eastern Victoria consist of a vast thickness of monotonously uniform, rhythmically deposited geosynclinal sediments, predominantly graded (turbidites), with grain size generally in the range of clay to fine sand. Quartz sandstones are uncommon, though they are more prominent further W. in the Myrtleford-Tabberabbera-Bruthen belt, and within the fault-bounded slices of

SIMPLIFIED DIAGRAM OF STRATIGRAPHY OF EAST GIPPSLAND

	BUCHAN – INDI – BINDI DISTRICT	MITTA MITTA – GIBBO RIVERS DISTRICT	CROAJINGOLONG DISTRICT
CAINOZOIC	Basalts; marine and non-marine sediments		
TRIASSIC	*Intrusion of syenite and granite porphyries (Benambra) etc.*		
UPPER DEVONIAN	MT. TAMBO GROUP (*Mt. Tambo area*)		MERRIMBULA (GROUP) LOCHIEL FORMATION EDEN RHYOLITE
	Unconformity – Tabberabberan Orogeny – (*Intrusion of Ellery Granodiorite, Gabo Island Granite, extrusion of Eden Rhyolite.*)		
LOWER DEVONIAN	BUCHAN GROUP BLOCK FAULTING AND PLANATION SNOWY RIVER VOLCANICS TIMBARRA FORMATION		
	Unconformity – Bowning Orogeny – (*Intrusion of Kosciusko Granodiorite, Bega Granite ?, Grey Mare Granodiorite, etc.*)		
SILURIAN	COWOMBAT GROUP (COWOMBAT FORMATION, TOWANGA FORMATION)	WOMBAT CREEK GROUP MITTA MITTA VOLCANICS	
	Unconformity – Benambran Orogeny – (*Intrusion of granites, generation of metamorphic rocks.*)		
UPPER ORDOVICIAN	Slates, turbidites, etc.		

FIG. 2—Correlation chart of the main stratigraphic units of east Gippsland.

east Central Victoria. These quartz sandstones are responsible in the main for the rugged topography of the Bowen Mountains E. from Accommodation Ck, and for the gorge of the Broadbent R. Because of tight folding, the monotony of the sediments, the frequency of faulting and the paucity of fossils, they tend to defy stratigraphic analysis. Slaty cleavage, small scale cross bedding in coarser units, and flute casts are common. Analogues in adjacent N.S.W. are the Adaminaby, Bogong Creek, Bolton and Kiandra beds and their probable equivalents (Moye, Sharp & Stapleton 1963). No tuffs or andesites comparable with those of the Kiandra Beds (Gisbornian) are known.

Upper Ordovician graptolites have long been known from Nowa Nowa, from areas to the N. about Wombat Ck and the Dart and Gibbo rivers, and from E. of the Snowy R. at Cabanandra, Cape Conran, Accommodation Ck (Deddick), Gattamurh Ck and McLaughlin's Ck (cf. Keble & Benson 1939 for refs.). More recently a number of localities have been discovered at Mt. Nunniong, South Buchan, Broadbent R., Barrabilly Ck, and Butcher's Ck. Pre-Darriwilian Da 4 horizons have not been discovered, but wide areas have yet to be examined in detail, so older horizons may well be present. For instance, on the Gibbo R. there is a descending succession to beds containing Da 4 graptolites, which in turn appear to be underlain by a great thickness of unfossiliferous sediments.

Silurian

The stratigraphy of the Silurian rocks of eastern Victoria has recently been summarized in this journal (Talent 1965); it will suffice therefore to indicate only the broadest features.

(1) *Sediments and Lavas*

The oldest unit, the Mitta Mitta Volcanics, lies outside the area under discussion in this Symposium; it consists of often highly fragmental ignimbrites (rhyodacites) with subordinate rhyolites, tuffs and minor tuffaceous sediments. It is overlain by the Wombat Creek Group, a sequence of marine conglomerates, limestones and generally fine grained terrigenous sediments at least 10,000 ft in thickness. One minor conglomerate half a mile upstream along the Mitta Mitta R. from its junction with Wombat Ck contains occasional granitic boulders, testifying to the presence of pre-Wombat Creek Group granites somewhere in the vicinity.

In East Gippsland the same sort of succession outcrops in a series of fault slices between Bindi and the headwaters of the Indi R. where it is known as the Cowombat Group. Silurian sandstones, limestones, marbles and fine-grained terrigenous sediments outcrop in this area from beneath the Early Devonian Snowy River Volcanics, with the fault slices tending in the S. to be radially focused on Bindi. In that area are the main developments of conglomerates (the Mount Waterson Formation) which though isolated by faulting, appear to be a lateral development of the basal unit of the Cowombat Group, the Towanga Formation. This is a unit with vast thicknesses of sandstones and some minor conglomerates and limestones, the latter having yielded poorly preserved fossils of Llandovery or Wenlock age. The succeeding units, grouped as the Cowombat Formation and so named because of the paramount importance of the richly fossiliferous development at Cowombat Plain, contains faunas of late Wenlock to early Ludlow age. Metamorphosed segments of the Cowombat Group cross the Ingeegoodbee R. and pass northwards into N.S.W. along the Suggan Buggan Range.

Silurian sediments are known sub-surface beneath the Snowy River Volcanics N. of Nowa Nowa (Talent 1959b), and from between Martin's Ck and the head of

Sardine Ck, but are better known N. of the border at Quidong, Cooma and areas farther to the N. Particularly at Bindi and in the vicinity of Cowombat Plain, relationships show the Silurian succession to have been folded prior to the extrusion of the Snowy River Volcanics. Relationships in general in the headwaters of the Buchan R. show that the Silurian rocks were intruded by the Kosciusko Granodiorite, and that this had been de-roofed before the onset of the terrestrial sedimentary and volcanic events indicated by the Timbarra Formation and the Snowy River Volcanics. The period of intrusion of the Kosciusko Granodiorite is therefore fixed within the time interval of the latest Ludlow and early Lower Devonian (Talent 1959a).

(2) *Latest Silurian or earliest Devonian granitic rocks*

Although the age of the Kosciusko Granodiorite and its ramifications about the Deddick, Timbarra and Buchan rivers can be fixed with some surety, the age of most other granitic bodies to the E. is not so precisely known. The Bega Granite is demonstrably pre-Upper Devonian in age, being overlain by equivalents of the Merrimbula Group. Extensions of it to the N. bearing other names and perhaps not related to it, such as the Boro Granite, are connected with metamorphism and mineralization of Silurian sediments; it would therefore seem to be of generally the same age as the Kosciusko Granodiorite.

It would seem that the Grey Mare Granodiorite has been responsible for the metamorphism of Silurian sediments adjacent to it along the Indi R. Because of extensive faulting, however, and some uncertainty as to how far the Grey Mare Granodiorite extends to the N., no firm decision can be made whether it is latest Silurian-earliest Devonian or younger. The former age range is favoured on regional grounds. Tentatively the granitic masses at Bonang, Delegate River and Irondoon Range, and scattered among the metamorphics N. and S. of Murrungowar are regarded as being also of this age.

The age of the Bete Bolong diorite intrusions and of the Crowstick and Barrabilly diorites in the N. is not definitely known, but is thought to be either latest Silurian to earliest Devonian, or, at the latest, late Middle Devonian to early Upper Devonian.

The fold pattern of the Ordovician basement is to some degree fan-wise, striking approximately NW. to NNW. in the watersheds of the Mitchell, Wentworth and Nicholson rivers, more or less N. in the watersheds of the Gibbo and Buckwong rivers, and with a common trend slightly E. of N. in the watershed of the Snowy R. This fold pattern is therefore disharmonic with the fan-wise arrangement of the Silurian, which trends NW. along the Mitta Mitta R., NE. in the Limestone Creek-Indi River Area (though swinging progressively northwards to the N.), and becoming more easterly eastwards from Bindi. Care is thus necessary in attributing various fracture and shear patterns within the metamorphic belt to a given tectonic episode, using such evidence alone.

Devonian

(1) *Snowy River Volcanics and Timbarra Formation*

Thick sequences of non-marine conglomerates, sandstones, siltstones and minor ignimbrites at least 5,000 ft in thickness constitute the Timbarra Formation, which rests unconformably on the Kosciusko Granodiorite and is overlain by the Snowy River Volcanics. It occurs principally to the W. of Buchan and to the W. of Wulgulmerang (Fletcher 1963; E. R. Woodford, unpub.). Subsequently the Snowy

Limestone Creek, Murendal River. (*A. W. Howitt, 1876*)

River Volcanics complex of more than 10,000 ft of rhyodacites and tuffs with subordinate rhyolites, andesites, keratophyres and basalts accumulated over much of Victoria E. of the Tambo R. The sequence has obviously thinned to a few hundred feet of ignimbrite (rhyodacite) at Errinundra where it occurs interbedded between marine terrigenous sediments below, and limestones correlated with the Buchan Caves Limestone, above. The maximum thickness preserved is in the Wulgulmerang area where the sequence is terminated by tuffs, red beds sometimes with pisolith horizons (Whincup 1947), prominent conglomerates composed mainly of rounded volcanic boulders (Boundary Creek Conglomerate of Ringwood 1955), and with a minor development of trachyandesite (Joplin 1964). A more detailed account of the Snowy River Volcanics succession can be found in the works of Teale (1920), Gaskin (1943), Cochrane & Samson (1947), Ringwood (1955a and b), Fletcher (1965) and Bradley (in press).

(2) *Buchan Group*

Evidence from Bindi, best seen at Mt. Waterson, shows that the Snowy River Volcanics and the underlying Cowombat Group were subjected to epeirogenic block faulting with planation prior to deposition of the Buchan Group, since the lowest unit of this Group rests on the planed surfaces of blocks of Snowy River Volcanics and Cowombat Group sediments (Talent 1965). The same epeirogenic event and planation is apparent in the Buchan area (see discussion under tectonics) and is probably the main reason for the Buchan Caves Limestone resting on different units of the Snowy River Volcanics in different outliers, though the Limestone nowhere rests on the youngest unit of the volcanics, the Wulgulmerang Tuffs. However, the possible lenticularity of the volcanic units must be considered. Yet despite this tectonism, there is remarkable uniformity in lithologic and faunal succession between the various outliers of the Buchan Caves Limestone scattered between Buchan, Bindi, the Indi R. and Errinundra, suggesting original deposition on a near planar surface termed the Buchan-Indi-Combienbar Shelf (Talent 1965). This term was coined to stress this remarkable homogeneity, in the face of recurring statements in the literature that Middle Devonian sedimentation took place in isolated basins. Such an idea originated apparently with a misreading of Howitt, who repeatedly referred to the physiographic expression of these calcareous areas as basin-like, but who recognized them as formerly connected, and deposited 'at a distance from land in seas of moderate depth' (Howitt 1876, p. 209). The preservation of these disconnected bodies is due to a combination of folding and faulting.

For accounts of the stratigraphy and palaeontology of the Buchan Group reference should be made to the publications of Teichert & Talent (1958) and Talent (1965). In the latter publication the Pyramids Member was regarded as being late Emsian or Eifelian and the overlying Murrindal Limestone more probably Eifelian. Later work by Philip (1966) on conodonts would suggest slightly earlier ages with the Murrindal Limestone not extending up to the Eifelian.

Deformation of the Lower to early Middle Devonian sequences of south-eastern Australia took place principally in the interval between the close of the Eifelian and some time early in the Upper Devonian (Tabberabberan Orogeny). This was followed by intrusion of the Ellery Granodiorite which metamorphosed the Lower Devonian to early Middle Devonian succession at Errinundra, and has not affected the overlying Upper Devonian succession. The Gabo Island Granite is referred to the same epoch; it has been shown to intrude the Eden Rhyolite, but is overlain unconformably by arkosic conglomerates and sandstones of the Merrimbula Formation (Hall 1959).

(3) *Upper Devonian*

The Upper Devonian sequence in eastern Victoria is characterized by predominance of terrigenous sedimentation over rhyolitic and basaltic vulcanism. The succession is best known in the Eden district where the Eden Rhyolite, a sequence of over 1,000 ft of rhyolites, ignimbrites and agglomerates differing petrologically from the Snowy River Volcanics, is overlain unconformably by the Lochiel Formation, up to 1,400 ft of basalts with subordinate rhyolites, arkoses, conglomerates, sandstones and red shales. The unit thins to the S. and is lost in the vicinity of Eden, where it is overlapped by the Merrimbula Formation. This latter consists of at least 2,500 ft of arkosic conglomerates, arkoses, sandstones, siltstones and shales; part of the succession at Eden has yielded a meagre marine fauna dominated by *Cyrtospirifer* and *Cyphototerorhynchus*, indicating a Frasnian and probably late Frasnian age. SW. and S. from Eden the Merrimbula Group outcrops as a series of outliers, the main belt extending through Wonboyn and into Victoria at Cape Howe and Mt. Carlyle. Outliers at Mt. Imlay and Timbillica help to establish the former continuity of this succession with the four *en echelon* outliers in Victoria: along the Genoa R. (known as the Genoa River Beds), Buldah, Combienbar and Club Terrace. All these owe their preservation to structural factors (Spencer-Jones 1967).

The Mt. Tambo Group, outcropping in a belt extending from Mt. Bung through Mt. Tambo to Mt. Shanahan near Bindi, consists of 10,000 ft or more of well-bedded reddish to purplish shales and sandstones, with conglomerates up to 40 ft thick. The sandstones and coarser sediments are poorly sorted and commonly cross-
bedded reddish to purplish shales and sandstones, with conglomerates up to 40 ft
bedded; arkoses are not infrequent, as for example at Mt. Shanahan. The Group is

unconformable on the Omeo Schists and Gneisses to the E., faulted against the Snowy River Volcanics and Buchan Group to the SE., and on the W. it has been intruded by The Sisters Granite Porphyry.

Triassic

The landscape about Benambra is dominated by inselbergs and rugged hills of syenite and trachyte together with more subdued hills of granite porphyry. The granite porphyries and syenites with transitional types have been grouped as one igneous cycle (Crohn 1950). Evidence from a number of localities, such as Mt. Little Tambo, suggests that granite porphyries and syenites have intruded the trachytes. The syenites and associated intrusions were formerly regarded as Upper Devonian or early Carboniferous in age, but a K/Ar date has shown them to be of late Triassic age (McDougall 1965).

There is no evidence for igneous or tectonic activity during the remainder of the Mesozoic or early Tertiary.

Cainozoic

Cainozoic basalts occur scattered across the area between Bonang, South Buchan and Gibbo River, with the largest masses responsible for the tablelands about Gelantipy-Wulgulmerang and the Nunniong-Nunnet plains. A *Cinnamomum* flora found in association with one outlier on the Deddick road between Little River and McKillop's Bridge is evidence for a mid-Tertiary age for these basalts, though with some qualification because of the persistence of this flora, broadly defined, until later Tertiary (Gill 1952). With the exception of the Morass Creek basalts N. of Benambra, all of these scattered Cainozoic basalts occur as outliers. This indicates that they formerly occupied a much greater area, extending down the Mitta Mitta gorge and for some distance up the valley of Wombat Ck. The Morass Creek basalts lack eruption points: features formerly regarded as such are in fact inliers of Silurian bedrock, and the basalts are remnants of stagnant surfaces being reduced by Morass Ck and the Gibbo and Mitta Mitta rivers. Small outliers of basalt near Club Terrace, from their physiographic situation, are clearly to be regarded as mid-Tertiary in age. Mapping of small outliers of basalt S. and W. of Buchan (Fletcher 1963) has helped demonstrate that the pre-basaltic drainage for much of this area was probably, as now, directed N.-S. Outliers farther N. indicate an ancestral Buchan R. more or less in its present situation, with a large tributary from Nunniong Plains in the W. The same N.-S. alignment is shown by the Wulgulmerang-Gelantipy-W Tree basalts. Basalts at a lower level near the Snowy R. suggest an ancestral Snowy valley more or less in its present situation as far back as mid-Tertiary times.

The Cainozoic succession about Lakes Entrance and to the W. is well known from the works of Carter (1964), Bird (1965), Jenkin (1968) and Hocking & Taylor (1964). The latter refer to the coastal area E. from Lakes Entrance and from it inland up to 6 miles, as the 'Lakes Entrance Platform'. Initial marine Cainozoic transgression over the platform consists of micaceous and sideritic sands with basal gravels passing up into glauconitic sandstone and in turn to dark micaceous, often sandy, marl. This unit, the Lakes Entrance Formation, is of Oligocene and possibly uppermost Eocene age, and is of the order of 150 ft thick in the vicinity of Lake Tyers (Hocking & Taylor 1964). It is overlain by the Gippsland Limestone of Miocene age which forms prominent outcrops in cliffs along the two arms of Lake Tyers at Toorloo and S. of Nowa Nowa, at Hospital Creek (Tildesley R.), and on the W. side of the Snowy R. about Orbost. A decline in carbonate sedimentation and an influx of terrigenous sediments is found in the succeeding latest Miocene beds known as the Tambo River Formation, representing an early phase of marine regression. This unit is known as far E. as Lake Tyers but has not yet been found further E. Marine sedimentation continued to contract towards the Lakes Entrance district with a last marine Tertiary unit, the Jemmy's Point Formation, consisting of calcareous sands and silts passing upwards into lagoonal sediments of the Mycrimalang Formation (Wilkins 1963). These in turn doubtless grade landwards into the later Pliocene-to-Pleistocene Haunted Hills Gravels which, loosely defined, extend as a veneer northwards to Buchan, eastwards to Mallacoota, and into N.S.W. about Timbillica and Cape Howe. Evidence from the elevation of marine shell beds at various localities in the Gippsland Limestone shows that these sediments have been mildly upwarped landwards to as much as 180 feet near the Colquhoun granite quarry (Wilkins 1963). The same upwarping is reflected in the way each of the Tertiary formations dips seawards [allowance being made for initial dip].

The Pleistocene and Holocene history of the area E. of Lakes Entrance is not well known, but the work of Jenkin (1968) and his predecessors provides a detailed account of areas to the W.; this would be the basis from which the coastal history to the E. would be judged. No attempt is here made to establish a sequence of events in the development of coastal barriers, lagoons, marshes and alluvial deposits in this area; these deposits are arranged in *en echelon* fashion, the more notable developments occurring about the mouths of the Snowy, Bemm, Cann, Thurra and Genoa rivers. A mid-Holocene high sea-level recognized at many localities farther W. is exemplified by dates of 3780 and 3560 years B.P. obtained for two superposed shell beds at Howe Flats E. of Mallacoota (E. D. Gill, pers. comm.).

Attention is drawn to the deep kaolinization of the granitic rocks of the area, readily appreciated in cuttings on the Princes' Highway, and to possibly lateritic profiles developed on Cainozoic sediments such as those along the Cann River-Cape Everard road. E. D. Gill (pers. comm.) has pointed out the significance of these for possible discrimination of his (Gill 1964) mid-Tertiary Nunawading and Lower Pliocene Timboon terrains.

Structure

A region of anastomosing lanceolate and deltoid fault blocks occupies an area centred on Buchan. A series of major faults fans out from Nowa Nowa towards Bindi in the NW. and Bonang in the NE. The same arcing pattern is interrupted by Triassic granitic and syenitic intrusions about Benambra, but extends beyond this, passing to the N. and NW. into a region of generally less spectacular rhomboidal fault blocks indicative of a generally more homogeneous stress pattern. To the NE. the pattern of lanceolate fault blocks becomes more attenuate as it passes northwards towards Tumut and Canberra. The structural pattern is less clearly known E. of the Bonang Highway for in this area there is a general lack of the wide variety of Silurian and Devonian sedimentary and volcanic units that have enabled deciphering of the broader tectonic history of the area to the W.

A. The Snowy River Volcanics Belt and Areas to the North

The tectonic history of eastern Victoria can be deciphered in more detail in the areas in, and adjacent to, the Snowy River Volcanics belt, the Mitta Mitta Volcanics belt, and the area about Benambra, for in this area the multiplicity of stratigraphic units and igneous bodies enables the sequence of tectonic, stratigraphic, volcanic, plutonic and palaeogeographic events to be sorted out.

Broadly speaking, Bindi is the focal point for convergence of a number of arcing fault systems. The Indi Fault from the NE. swings southwards as it crosses the Tambo River N. of Bindi, and then swings progressively towards the SE., heading approximately in the direction of Buchan. It is poorly known S. of the Junction Creek-Little River Divide, though reconnaissance mapping seems to indicate that the intensity of movement was dissipated in a series of parallel faults. But along the same trend about 12 miles to the SE., near Mt.Gilgroggin at the junction of the Timbarra R. and Wilkinson Ck, the mapping of Fletcher (1963) has documented a fault boundary between the early Devonian Timbarra Formation and Ordovician sediments on the W. The same fault boundary then swings slightly W. of S. in the general direction of Lakes Entrance until lost beneath the Cainozoic cover of the coastal downs.

Net movements along the Indi Fault during the Tabberabberan deformation resulted in downthrow to the E. and preservation of the vast thickness of the Silurian Cowombat Group, early Devonian Timbarra Formation, early Devonian Snowy River Volcanics, and late Lower Devonian Buchan Group. All these units were completely removed from adjacent parts of the upthrown block to the W. prior to deposition of more than 10,000 ft of Mt. Tambo Group sediments. That all these units were removed and that the Upper Devonian sediments on the westerly block now rest directly and unconformably on metamorphics and Ordovician sediments is an impressive measure of the displacement along this fault and the erosion that occurred during roughly Middle Devonian times. Preservation of the Mt. Tambo Group, on the other hand, is sound evidence for a reversal of movement on the fault at some time since the Devonian. Part at least of a westerly block was downthrown and the Mt. Tambo Beds stripped from the easterly block. Needless to say, there must have been formerly some Mt. Tambo Beds on the easterly block, for they are truncated by the Indi Fault. Nevertheless, the overall displacement in relation to Tabberabberan and later, presumably Kanimblan (Lower Carboniferous) movements, was one of downthrow to the E.

Evidence is lacking for the existence of the Indi Fault prior to deposition of the Buchan Group in late Lower Devonian times, but the harmony of its trend with

Junction Buchan and Murendal Rivers. (*A. W. Howitt, 1876*) that of a system of faults sweeping south-westerly from the upper Buchan R. towards Bindi is apparent. This fault complex includes the Hell's Hole, Carrabungla and Reedy River Faults (Talent 1967) and, though the pattern of faulting E. of Bindi is known in broad fashion only, the system as a whole sweeps in towards Bindi, jumbling blocks of Cowombat Group (Silurian), Snowy River Volcanics (early Devonian) and, further out, blocks of schisted Ordovician sediments and granitic rocks of presumed early Devonian (pre-Snowy River Volcanics) age. And yet the lowest unit of the Buchan Group was deposited indiscriminately over the planed surfaces of these blocks (Talent 1965), testifying to post-Snowy River Volcanics, pre-Buchan Group block faulting and planation. It seems reasonable to assume that the parallel Indi and Bindi faults to the N. and S. were in existence at that time and that it was these latter only of the system which were involved in subsequent displacements. As far as stratigraphic evidence is concerned, there would be no grounds for inferring pre-Middle Devonian movements along the Bindi Fault, but its intimate associaton with the whole system of the Indi, Hell's Hole, Carrabungla and Reedy River Faults leads one to assume pre-Buchan Group movements as well as movements in the Tabberabberan and Kanimblan diastrophic epochs. The post-Palaeozoic igneous activity of the Benambra district, now dated as late Triassic (McDougall 1965), is associated with relatively minor tectonic disruption. There is a general concordance of trachytes associated with the syenites scattered over an area of about 100 square miles, the coarser plutonic rocks of this association as it were exhumed, though retaining remnants of trachyte 'skin'. Though the example is small and the tectonic pattern obscured by alluviated valleys and poor outcrops between the igneous masses, one is led to the tenuous conclusion that this area has not been dislocated on anything like the scale involved, for instance, in the downthrow and preservation of the Mt. Tambo Beds along the Indi fault. A still more tenuous conclusion is that large scale fault movements had ceased in this area by late Triassic times.

N. of Benambra the Mitta Mitta Volcanics and Wombat Creek Group outcrop within an attenuate fault-bounded strip, structurally a graben but no longer presenting this physiographic form. The bounding Wombat Creek and Morass Creek Faults converge towards the foothills of The Brothers NE. of Benambra, where their presence is doubtless indicated by Silurian sediments about Pyle's Deposit. These large scale faults have not been detected further S. in the Mt. Tambo-Sisters region of Upper Devonian sediments and Triassic igneous rocks. These would appear to conceal the extension of these faults and thus to set an Upper Devonian upper limit for appreciable movements along them. On the other hand, their trends line up well with the southward to south-easterly swing of the Indi Fault about Bindi and accordingly they could be assumed to have been confluent. Once again, the evidence indicates more profound faulting before the Upper Devonian than during or after Upper Devonian times.

A number of moderate to large scale faults have been detected bounding or within the Snowy River Volcanics belt in the general vicinity of Buchan and Gelantipy, strewn across the area between the Timbarra and Yalmy rivers. The major pattern is a N. to NE. directed fan, the most westerly already discussed as a probable extension of the Indi Fault, and the most easterly the Yalmy Fault, along which the Devonian sequence has been downthrown against an easterly block of Ordovician sediments on which Silurian or Devonian units are lacking for some miles. The Yalmy Fault and its prominent crush zone would therefore appear to be one of the major structural features of eastern Victoria.

Mapping of the Ordovician enclaves within the Snowy River Volcanics belt

Fig. 3—Pattern of igneous intrusions and larger scale faults in eastern Victoria.

about Nowa Nowa (most recently by Bell 1959) and the discovery by drilling of Silurian sediments beneath the intervening strips of Snowy River Volcanics (Talent 1959) reveal the enormity of fault displacements in this area. Further N. along the strike of these faults there is an obvious contrast between the deformation and scale of faulting within the Buchan Group, which there lies as a drape over the jigsaw of fault blocks. This contrast has been adduced as evidence for block faulting and planation of the Snowy River Volcanics prior to deposition of the Buchan Group, an event more readily discernible at Bindi (Talent 1965). Northwards from East Buchan, fault blocks of Ordovician sediments and granitic rocks about Mt. McLeod and on the New Guinea Road near Butcher's Creek show the continuing importance of displacements by faulting within the Snowy River Volcanics belt (Bradley, in prep.). Two easterly directed tongues of Snowy River Volcanics extend across the Snowy River towards Bonang, the more northerly including the Bowen Mountains about Deddick, and the southerly occupying much of the watershed of the Roger R. Though the northerly margin of the Mt. Deddick tongue appears to be in essence a normal unconformable contact with Ordovician sediments and earliest Devonian or latest Silurian granitic rocks, the intervening tongue of Ordovician sediments and granitic rocks in the valley of the Snowy R. about Campbell's Nob and eastwards up the watershed of the Broadbent R. is largely controlled by faulting. This is particularly apparent near the mouth of the Broadbent R. where thin slices of Ordovician sediments are interleaved with slices of Snowy River Volcanics. The main E.-W. boundaries of the Volcanics N. and S. of the Broadbent River are faults; these E.-W. structural trends are repeated N. of Gillingal and N. of Timbarra where N.-S.-striking belts of Snowy River Volcanics and an attenuate strip of Buchan Caves Limestone are cut off at right angles by E.-W. faults (Fig. 3). The occurrences of limestones within the Snowy River Volcanics belt at Gillingal, Jackson's Crossing, Butcher's Creek and at the Murrindal or Hume Park lead mine are all associated with faults.

B. East of the Snowy River Volcanics Belt

For pre-Upper Devonian plutonism and tectonism E. of the Bonang Highway and E. of the Snowy R. in adjacent N.S.W., evidence is scattered. At Errinundra (Thomas 1947) a sequence of tuffaceous sediments and ignimbrites overlain by limestones contains fossils that, despite poor preservation, strengthen the analogy with the Snowy River Volcanics and Buchan Group farther W. These Lower Devonian units were folded into a syncline and down-faulted prior to deposition of Upper Devonian sediments of the Club Terrace-Bemm River outlier. The relationships of the Silurian marbles and conglomerates between Martin's Ck and the head of Sardine Ck to the Ordovician bedrock of eastern Victoria is not known, but at Quidong, between Delegate and Bombala, a gently folded Silurian succession is faulted against, but also demonstrably unconformable over, tightly folded Ordovician sediments. Other scattered occurrences of Silurian sediments to as far E. as Bendethera near Moruya indicate the former widespread and presumably continuous Silurian seas over the entire area, and presumably everywhere essentially unconformable with the previously folded Ordovician succession. The preservation of these scraps of Silurian and Lower Devonian seems to be everywhere connected, at least in part, with major faulting.

Small tectonic basins preserving Upper Devonian sediments at Combienbar, Buldah and Club Terrace bear witness to the existence of a number of strong N.-S. post-Devonian faults (Spencer-Jones 1967). These faults and the attitudes of the basins indicate the presence of a major wrench fault, the Combienbar Wrench, in which the north-westerly block has moved upwards and to the NE. relative to the south-easterly block in which the Upper Devonian sediments have been nipped in and preserved. The Berridale Wrench extending from Disaster Bay north-westerly through Berridale towards Kiandra (Lambert & White 1965) seems to be conjugate with the Combienbar Wrench.

A further wrench with lateral translation of 3 to 4 miles, here termed the Tombong Wrench, is postulated as sweeping up northwards from this vicinity of Mt. Jack through Goongerah; it would thus account for the apparent northerly migration of a western sliver of the Ellery Granodiorite. Extension of this line to the NNE. into N.S.W. would pass through Tombong and close to the W. side of the Quidong Silurian outlier where there is known structural complexity, and serpentinites and other sheared rocks are present (Relph & Wynn 1960). The trough at Quidong contains Silurian sandstones passing up into shales and limestones, and another between Tombong and Delegate contains Silurian or Devonian sandstones; these can be regarded as large scale synforms produced in part as a result of lateral translation along this line, the more westerly block riding northwards (dextrally) relative to the more easterly block. A small body of granite between Mt. Koolabra and Bendoc may be a fragment torn from the Delegate River intrusion by the wrench. The southerly extension of the wrench could well sweep down and form part of the western margin of the Mt. Kuark-Murrungowar metamorphic belt. The mapped outline of the Ellery Granodiorite suggests a fault, downthrown to the E., passing through the pluton and forming the eastern boundary of the Mt. Kuark-Murrungowar metamorphic belt.

Dislocation of the Ellery Granodiorite would be evidence for post-Upper Devonian movement along the Tombong Wrench, but the magnitude of possible older movements cannot be determined from the stratigraphic units located along its presently known extent. The Tombong Wrench, viewed simply, could well extend beneath the Monaro basalts to join with the Murrumbidgee Fault system and so to Canberra (cf. Canberra 4 mile Sheet, Bureau of Mineral Resources). Likewise the Combienbar Wrench, if projected N., could join in some way with the Shoalhaven Fault system.

The bedrock E. of the Bemm and Combienbar rivers is largely made up of two N.-S. tongues of granodiorite divided by a narrow belt of Ordovician terrigenous sediments averaging 6 to 10 miles in width. The granitic tongues join near the border SE. of Nungatta, though the belt is echoed further N. by a thin screen of Ordovician sediments W. of Towamba. The western margin of the Ordovician belt is faulted E. of Mt. Drummer on the Princes' Highway. The general northerly trend of this fault sweeping up the boundary between the Bega Batholith and the Ordovician sediments is the same as those bounding the Upper Devonian outliers farther west. It may have originated earlier, but can be reasonably assumed to have, like them, experienced appreciable movement during the post-Devonian (?Kanimblan) era of wrenching.

The Upper Devonian sediments N. of the border in large measure owe their preservation to faulting. The eastern bounding fault of the Platts-Maharatta enclave extends towards the Victorian border as the western boundary of the Bega Batholith. The Upper Devonian outlier at Mt. Timbillica appears to be truncated by faulting to the N. and S. Even allowing for unconformities between the Eden Rhyolite, the Lochiel Formation and the Merrimbula Group about Eden, the pattern of mapped outcrops (Hall 1959) seems to indicate that the problem there too, may be complicated by block faulting, e.g. NE. of Towamba in the vicinity of the Sugarloaf goldfield.

The overall pattern of the various Devonian enclaves E. of the Bonang Highway thus emphasizes the magnitude of the post-Devonian tectonic movements in their vicinity. It seems reasonable to assume that intervening areas now lacking such distinctive markers have not escaped comparable tectonism.

C. Cainozoic Movements

Evidence of Cainozoic tectonic movements in the area is far from widespread. None of the Cainozoic basalts of the Wulgulmerang-Gelantipy-W Tree, Bonang, Nunniong-Nunnet or Morass Creek areas show obvious disruption by faulting. Basalts within the valley of the Snowy River E. from, and at a lower level than, those at Wulgulmerang may be construed on casual appraisal to owe their reduced elevation to later Cainozoic faulting, but evidence for this is otherwise absent. These mid-Tertiary, approximately Oligocene, remnants seem rather to be related to an older, less incised valley of the Snowy R., and are perhaps of more interest as a yardstick for appreciating the rate of excavation of the gorges of the Snowy R. through resistant Snowy River Volcanics to the S.

On the present evidence the cause of the abrupt seaward swing of the marine Tertiary boundary in the Orbost-Marlo area could be explained either by warping, or by irregularity of the shore line in Miocene times. The history of Cainozoic warping, particularly in Plio-Pleistocene times, westwards from Lakes Entrance and in a general way parallel to the margins of the Gippsland Basin is given by Jenkin (1968). While the importance of structure within the Gippsland Basin has become well known, it could be said that theories of warping of the highlands with consequent influx of terrigenous sediments have been over-emphasized at the expense of climatic change, particularly with regard to the widespread, predominantly Plio-Pleistocene 'torrent gravels'. The deposition of the 'gravels' is so extensive and relatively abrupt that it is difficult to visualize it as resulting from block faulting and doming and rejuvenation of streams. The focus of maximum uplift was over 100 miles N. of the present 'torrent gravels' sheet, and the elevation involved in that area was no more than about 2,000 ft since approximately Oligocene times, the pre-basalt relief of the Monaro-Kosciusko region being no more than 3,500 to 4,500 ft according to Craft (1933b). Rather, the 'torrent gravels' give the impression of having been distributed across the piedmont areas by streams wandering about like so many loose hoses with greatly augmented flow—the products of a pluvial cycle or cycles.

Some fault movements in Cainozoic times can nevertheless be documented: the Tawonga Fault over-riding river gravels (Beavis 1960); the small horst at Benambra damming Lake Omeo; the Buenbar Fault responsible for gorges on the Gibbo R., the Murray Gates gorge at Tom Groggin, the Devil's Grip gorge on the Swampy Plains R., and the extensive alluvial flats upstream from the fault at Beloka, Buenbar, Tom Groggin and Geehi. However, such Cainozoic movements have yet to be documented in the highlands E. of the Tambo R. The Tara Range may owe its prominence to Cainozoic faulting; the abrupt seaward swing of the marine Tertiary margin about Orbost may be the expression of a warp. These questions remain open.

Sequence of Tectonic Events

1. Tight folding of the Ordovician terrigenous sediments along axes trending between NW. and slightly E. of N. in early Silurian times.
2. Intrusion of granitic rocks in early Silurian times, and presumed generation of the Omeo Schists and Gneisses.

3. Extrusion of the Mitta Mitta Volcanics.

4. Deposition of the essentially terrigenous Cowombat and Wombat Creek Groups and their equivalents, the Quidong Group of N.S.W., with shoreline somewhere to the N. and NW. of Bindi.

5. Period of folding (Bowning Orogeny) producing a more widely spaced fold pattern than that produced during the early Silurian diastrophism; this pattern is fan-wise and disharmonic with that produced previously in the Ordovician sediments.

6. Intrusion of the Kosciusko Batholith and, almost certainly, of the Grey Mare, Bega, Irondoon, Murrungowar, Delegate and Marengo acid intrusives; presumed period of formation of the Mt. Kuark-Murrungowar metamorphic belt.

7. Deposition of the Timbarra Formation and accumulation of the Snowy River Volcanics following de-roofing of at least the Kosciusko Batholith.

8. Earliest discernible movement on the Indi, Bindi, Hell's Hole, Carrabungla and Reedy River Faults, the East Buchan Fault System, and presumably the Yalmy Fault.

9. Planation, followed by deposition of the Buchan Group after subsidence of the Buchan-Indi-Combienbar Shelf.

10. Period of folding (Tabberabberan Orogeny) producing broad regional folds in the Snowy River Volcanics with minor tighter folding in the less competent units of the Buchan Group. This event occurred post-Eifelian, pre-sometime in the early Upper Devonian. Movements along some major faults, best known for the Indi Fault. Certain older faults, e.g. Carrabungla and Hell's Hole Faults, suffered no displacement in this or later diastrophic events.

11. Post-orogenic plutonism typified by the Ellery Granodiorite and the Gabo Island Granite; this event was in part contemporaneous with those of 12, the Gabo Island Granite being presumably consanguinous with the Eden Rhyolite.

12. Widespread terrigenous sedimentation (Merrimbula and Mt. Tambo Groups) following the acid and basic vulcanism in the E. (Eden Rhyolite, Lochiel Formation), though perhaps not extending into Victoria.

13. Diastrophism resulting in appreciable movements along the Combienbar and Tombong Wrenches, presumably responsible in a general way for the generation of the synclinal bodies of Upper Devonian sediments about Combienbar, Buldah, Club Terrace and Genoa River. Tilting of the Mt. Tambo Beds and renewed movements, presumably soon afterwards, along the Indi Fault, causing reversal of previous movements with downthrow to the W.

14. Intrusion of the granite porphyry-syenite complex of the Benambra-Beloka-Marengo area in late Triassic times.

15. No record of events from Jurassic to Lower Tertiary times.

16 a. Downwarping and marine incursion over the Lakes Entrance Platform commencing in Oligocene or latest Eocene times and reaching its maximum extent in Miocene times.

b. Extrusion of Tertiary (?Oligocene) basalts down valleys oriented broadly the same way as present drainage..

17 a. Regression of the Tertiary seas in latest Miocene and Lower Pliocene times, doubtless fringed by non-marine terrigenous sediments, these advancing with retreat of the sea to form the Haunted Hills Gravels.

b. Movements along the Buenbar and Tom Groggin Faults; uplift of the Benambra Horst, damming Lake Omeo; minor upwarping near the coast.

18 a. Periglaciation of the highest peaks at some time or times during the Pleistocene.

b. Formation of the lunette-alluvial-swamp-sedimentary complex about Lake Omeo and Morass Creek.

c. Formation of older river terraces and alluvial fans e.g. along the Tambo R. about Swift's Creek.

d. Formation of the inner barrier of the Gippsland Lakes, and undefined shoreline accumulations further E.

19. Formation of the Holocene dune-swamp-sand-alluvial complex along the coastal fringe; associated with this is evidence of a mid-Holocene high sea level.

Economic Geology

There has been no major exploitation of metals in eastern Victoria. Small to moderate quantities of gold, silver, lead, molybdenum, iron and manganese have been mined, though presently known resources are insufficient for economic output, even with improved transport and access to the most remote prospects. There is greater potential in the industrial minerals, particularly the limestones, dolomites, building marbles and perhaps barite.

Gold has been mined from reefs and alluvial deposits scattered primarily across outcrops of Ordovician rocks eastwards from Buchan. Promising but small alluvial deposits are known from the Timbarra River, but no mines have been developed in that area. Generally small, but often surprisingly rich, mines have been worked in the Tara Goldfield S. of Buchan; all of these were located in Ordovician rocks except for the Monarch and the Tara Crown (or Armistice) mines—these were in Snowy River Volcanics (Teichert & Talent 1958). Perhaps the area most intensively prospected for gold is the Bendoc-Clarkeville-Bonang-Delegate River area. In the Bendoc-Clarkeville district a number of quartz reefs were worked to depths of 300 ft. The deepest shaft in the area is on the Rising Sun Reef at Bonang; it was sunk to 500 ft and the reef stoped out to the surface (Dunn 1909). Alluvial gold from these reefs and quartz stringers has been worked in alluvial flats along the Bonang, Delegate, Little and Bendoc rivers. A number of quartz reefs have been worked about Club Terrace, e.g. on Millionaire Gully (Kenny 1937a); the reefs repeat for three miles but, though surface prospects were often excellent, the quality did not persist in depth (Murray 1898; Stirling 1898). Farther E. there are minor gold occurrences, at Mallacoota for example, but these have no significance compared with the Yambulla Goldfield just N. of the border.

High *platinum-osmiridium* values have been obtained at the Bounder Mine, Errinundra (Kenny 1937).

Silver-lead mines and prospects are principally located about Buchan in the basal dolomites of the Buchan Caves Limestone (Teichert & Talent 1958), and at Deddick in granodiorite (Ferguson 1899). Ore with a high silver content has been mined at the Glen Shiel Silver Mine, Gelantipy East (Dunn 1907; Whitelaw 1921). There are a number of small lead shows scattered about the Buchan district from Ferntree Creek to Canni Creek and New Guinea Point on the Snowy R. A small quantity of silver-lead ore has been won from the silver mine at Boulder Flat S. of Errinundra. A few small lead-zinc bodies with ferruginous gossans occur in the Limestone Ck district and, though one of these assayed up to 36·6% zinc, none has proved economic (Mahoney 1936).

Small bodies of *molybdenum* ore occur at Wangrabelle where shafts have been sunk to a depth of 70 ft (Herman 1920); molybdenite has also been mined just N. of the border at Wog Mountain (Hall 1959).

Small quantities of *barite* have been mined at the Glen Shiel Mine, Gelantipy East, and on the Old Basin Road, East Buchan. It is known from a number of localities southwards from South Buchan, and at the Errinundra silver mine, Boulder Flat, Errinundra.

Graphite occurs in small quantities on Sundown Ck about 3 miles NW. of the Princes Highway at Bell Bird Creek (Herman 1920).

There has been no quarrying for *feldspar* in the area, though largish masses of soda-feldspar adjoining a gneiss-granite contact at Mt. Raymond E. of Orbost have attracted interest. Pegmatite dykes within the area are worthy of investigation, because about 4,000 tons of albite feldspar have been produced from a pegmatite dyke at Wog Mountain N. of the border (Hall 1959).

Small quantities of *tungsten* have been won at Mt. Bendoc, and at Fainting Range SSE. of Ensay (Thomas & Crohn 1952).

Monazite is a prominent component of alluvial deposits at Pinch Swamp Creek 5 miles N. of Bonang, though not in commercial quantities (Copland 1905).

Small *copper* lodes have been worked at Accommodation Creek, Deddick, and at Sardine and Wallaby Creeks on either side of the Bonang Highway (Dunn 1909a). Other small copper lodes are known about Limestone Ck, Ferntree Ck, the lower Timbarra R., The Basin near Buchan, and on the Snowy R. about 16 miles from Orbost; also at the Dominion Copper Mine on the head of Hospital Ck.

The *iron* ores of the Buchan-Nowa Nowa district have been extensively tested by drilling in recent years (Bell 1959), but tonnages have fallen far short of those necessary as a basis for a steel industry. One of three limonite bodies within the Buchan Caves Limestone SE. from Buchan has been quarried for 'scrubbing gas'; it is not being worked at present. (Teichert & Talent 1958). Northwards from South Buchan towards Jackson's Crossing the iron ores pass into essentially *manganese* ores, of which there are three main outcrops between The Basin and Jackson's Crossing (Kenny 1921, 1925; Thompson 1965).

The greatest potential mineral wealth of east Gippsland is in its *carbonate rocks*: the limestones and dolomites of the various bodies of Buchan Group sediments, the marbles of the Cowombat Group, and the soft limestones of the Gippsland Limestone. Green, red-brown, buff, magenta, white and flesh-coloured marbles are developed as lenticular bodies principally at Old Hut Creek, Bindi, and along Limestone and Stony Cks about 25 miles E. of Benambra. Outcrops of individual marble lenses are up to acres in extent and outcrop strongly; small quarries were opened up many years ago in the Limestone Ck-Stony Ck area (Whitelaw 1954), but these proved uneconomic due to method of working and, more particularly, prohibitive costs of transport. A small quarry was opened in the Silurian marbles between Sardine Creek and Martin's Creek about the turn of the century, but the most impressive deposit, the one at Bindi, remains untouched. *Dolomites* outcrop extensively at the base of the Buchan Caves Limestone, ranging in thickness from a few tens of feet at Bindi, Butcher's Ridge and Dead Horse Creek to a maximum thickness of around 200 ft at East Buchan where they have been quarried in small amounts for flux in steel making. Their low to moderate R_2O_3 content (sometimes as low as 0·25% Fe_2O_3) makes them potentially useful, for example, in the glass industry. The dolomite resources of the Buchan and adjacent districts is of the order of 100 million to 150 million tons. Devonian *limestones* were formerly quarried for building marble at three localities about Buchan: Commonwealth, Heath's and Cameron's quarries. Limestone of the Murrindal Limestone is presently quarried at Rocky Camp, 5 miles N. of Buchan for use in the paper industry at Maryvale. Because of ease of extraction, the Tertiary limestones exposed in valleys westwards from Orbost are an excellent source of agricultural limestone and perhaps for a future cement industry; they are presently worked on a small scale for agricultural limestone just N. of the Princes Highway on the Toorloo Arm of Lake Tyers.

Several small deposits of heavy minerals with patchy distribution of *ilmenite*, *zircon* and *rutile* are recorded from the vicinity of Cape Everard (N. H. Fisher, unpub.; G. Bell, unpub.); a possible 2000 tons of concentrate is thought to be present in the two largest deposits, the most promising being immediately E. of Point Hicks. Records from farther E., e.g. Betka R., have so far proved insignificant.

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